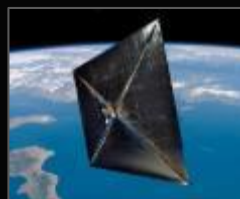




marshall



NIRPS Update to the Space Transportation Association July 16, 2015



Grand Challenges Facing Rocket Propulsion

Lack of integrated space strategies across Government Agencies and Departments

Frequent program starts & cancellations

Shuttle retirement

Uncertainty in future needs

Industrial base decline

Overcapacity of production capability

Rising supplier costs

Large solid rocket motor industrial base decline

Lack of multi-Agency vision

Reduce development & sustainment costs

Foster access to facilities & expertise

Support industrial base competitiveness & resilience

Collaborate across Agencies

Implement an integrated Science & technology plan

Invigorate the STEM pipeline

Overall decline in aerospace engineer demand

Lack of predictable long-term funding

Lack of sustained technology development

Aging workforce

Lack of defined space missions

Fewer engineers have technology development experience

Difficulty in access to government facilities

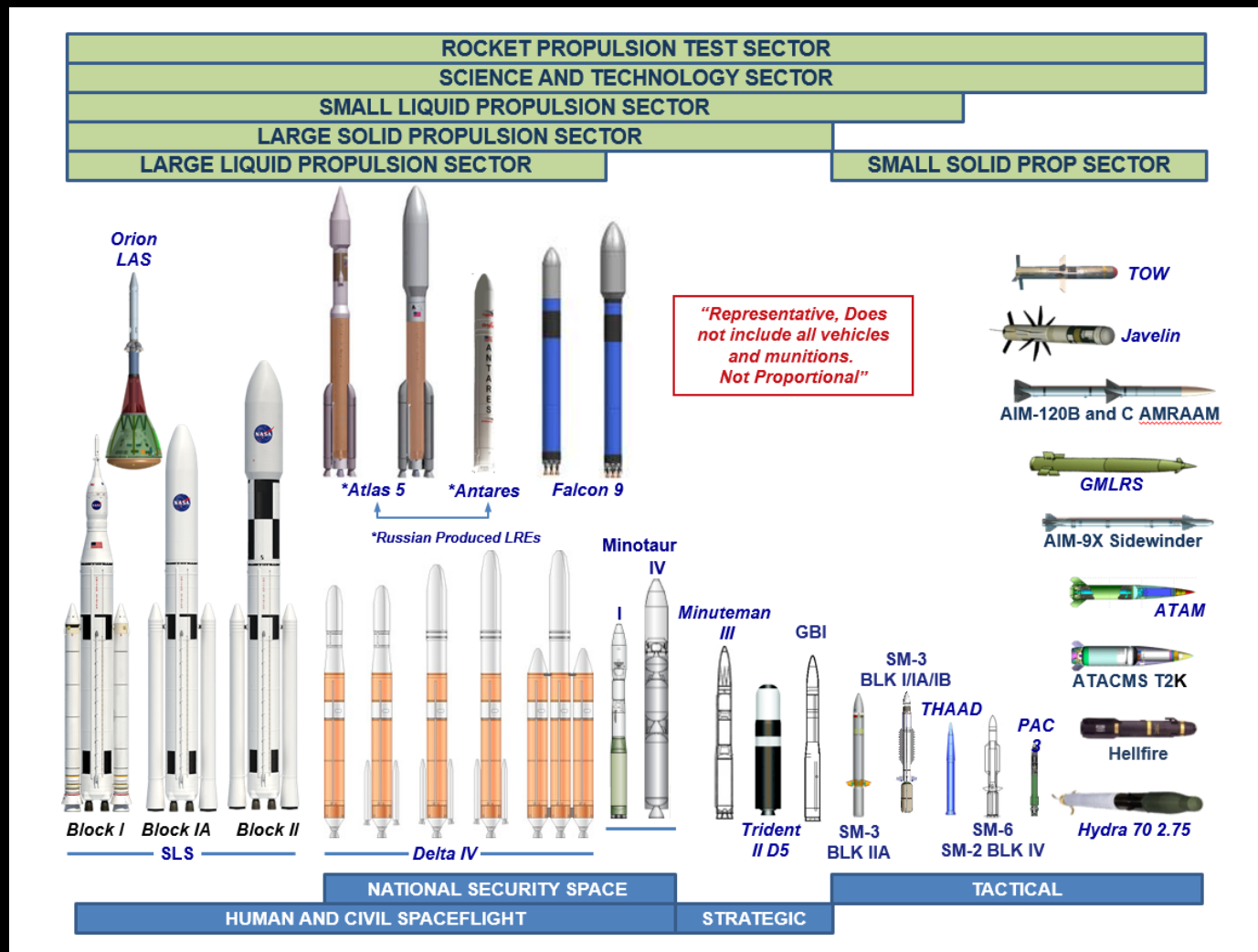
Systems infrastructure, supply chain, & skill base challenges

Loss of competitiveness in the global market

Addressing the Grand Challenges

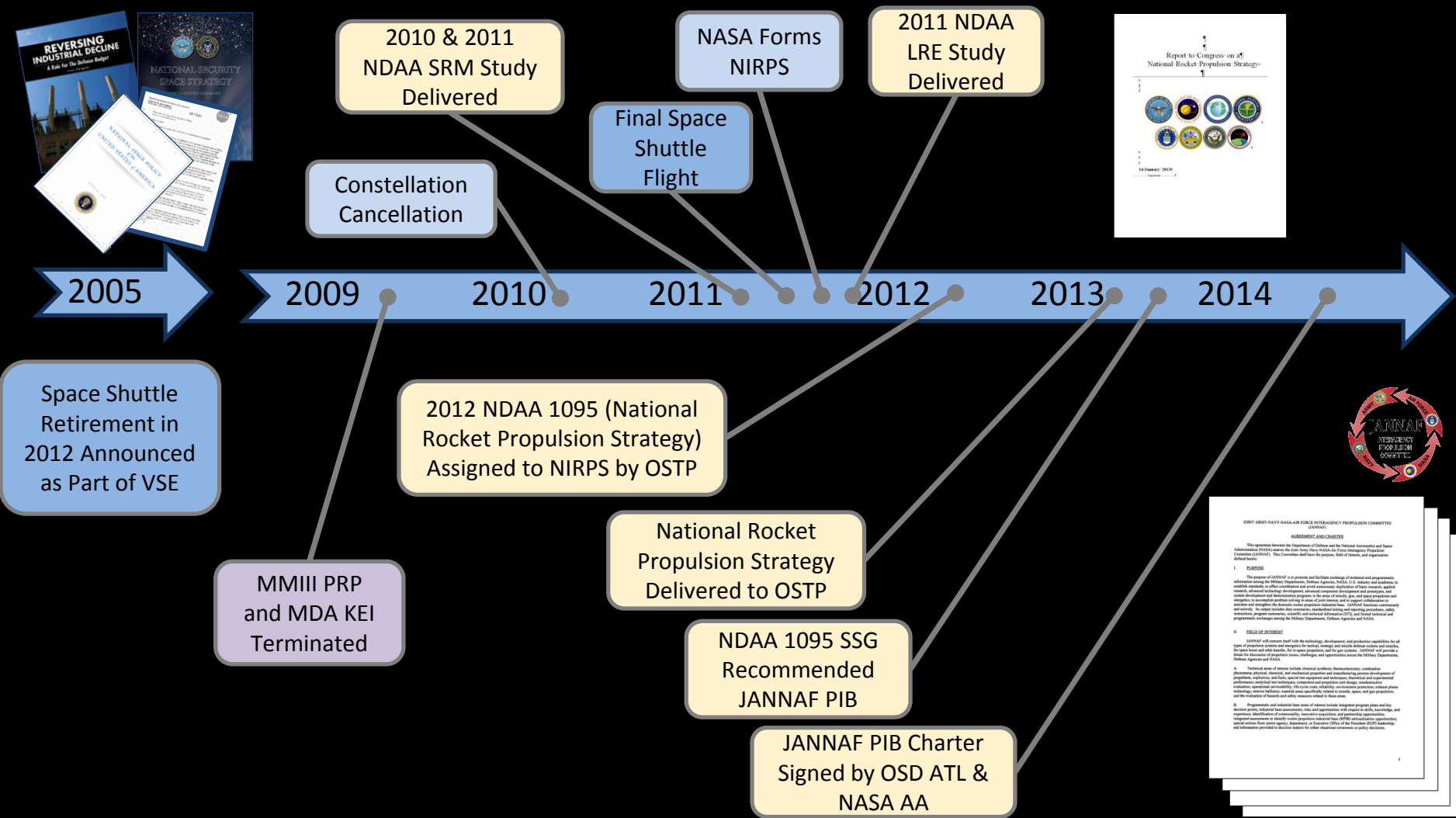
- Continued industry consolidation
- Even more interconnectedness between agencies, sectors and programs
- Limited USG rocket propulsion budgets
- Increasing need to lower costs while improving performance
- USG needs a way to collaborate and understand the whole picture of the RPIB
- JANNAF is a trusted, integrated Government-wide forum
- Augmentation of JANNAF with a Programmatic and Industrial Base (PIB) committee allows leveraging of resources, synergy with technical activities

Highly Interconnected Rocket Propulsion Industrial Base Serving Government and Commercial Needs



Changes in a program can have effects on seemingly unrelated programs

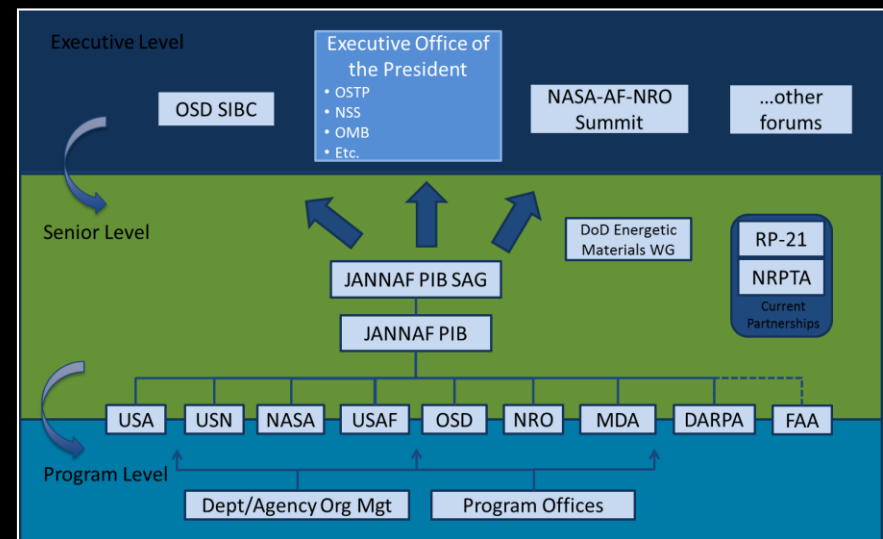
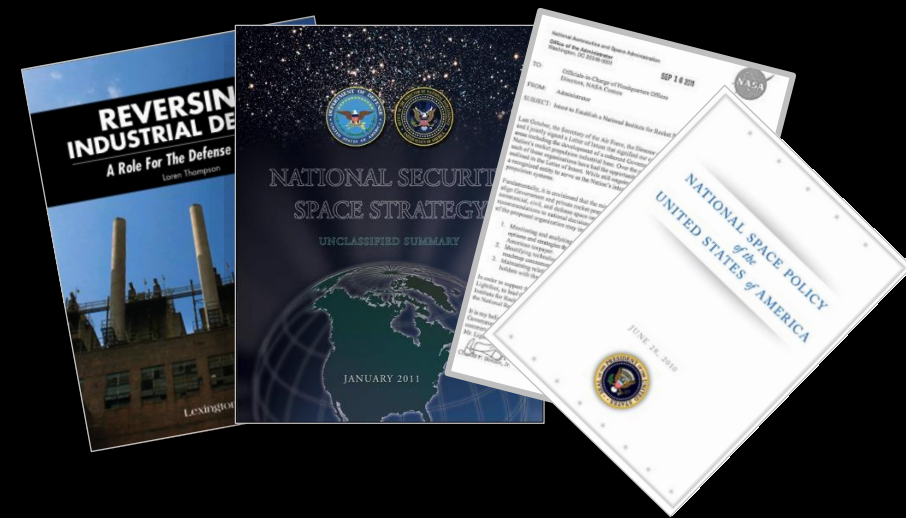
Path to Increased Government Propulsion Collaboration



NASA's NIRPS and JANNAF Programmatic and Industrial Base (PIB) Committee are Spearheading Collaboration

NIRPS and the JANNAF PIB are Executing Tasks of National Importance

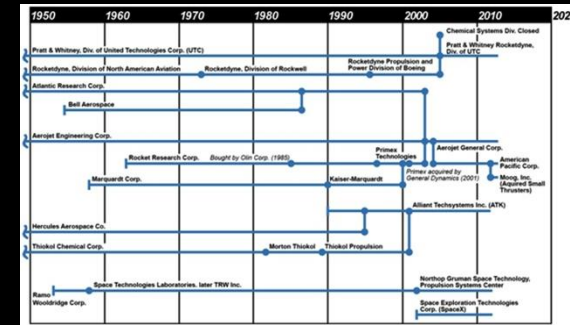
- Congressional and Administration concern about Rocket Propulsion Industrial Base (RPIB)
 - Widespread recognition of the problem
 - Sustainment of the solid rocket motor and liquid rocket engine industrial base is a national challenge that spans multiple departments and agencies of the U.S. Government.
 - Integrated approach among US Government Agencies
- PIB Supports Interagency Communication and Collaboration
 - JANNAF PIB Senior Advisory Group (SAG) established
 - Co-Chaired by NASA & DoD DUSD MIBP
 - **Members from Army, Navy, Air Force, NRO, MDA, OSD, & NASA**
 - JANNAF NASA/DOD PIB Charter Signed: June 2014



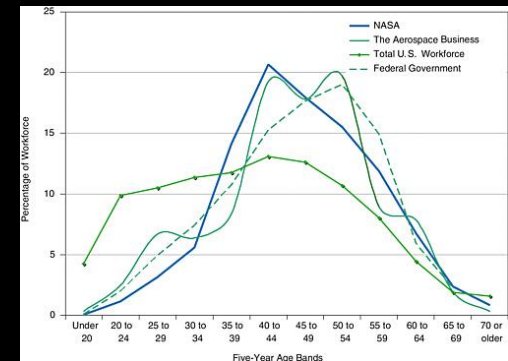
JANNAF Programmatic and Industrial Base Committee Leading Interagency Rocket Propulsion Collaboration



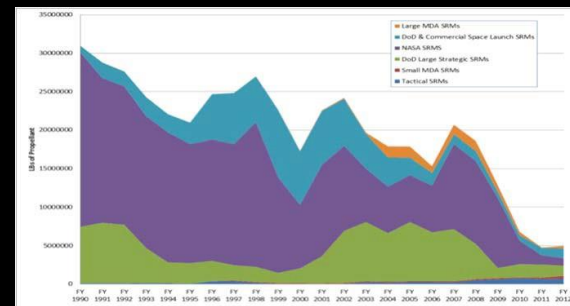
- The June JANNAF general meeting was the first with integrated PIB activities
- The First Senior Advisory Group meeting and presentation is scheduled for July 2015
- Products & Activities:
 - *Integrated (i.e. collated) program plans & key decision points*
 - Industrial base assessments
 - Risks and opportunities with respect to skills, knowledge, and experience.
 - Special actions from senior agency, department, or EOP leadership
 - Provide decision makers information for situational awareness or decisions in a timely and efficient manner
- Working Group Studies
 - Small Solid Rocket Motor Capabilities (2015 NDAA task)
 - Ammonium Perchlorate industrial base capabilities and alternatives
 - Domestic Boost Propulsion
 - Helium Stewardship Act of 2013 Effects



Consolidating Industry



Aging Workforce



Reduced SRM Production

JANNAF Contract Award

- Contract to provide technical and administrative support to JANNAF was awarded to the Center for Aerospace – Defense Research and Engineering at Johns Hopkins University on June 11, 2015
 - Contract award accomplished in time to ensure a seamless transition to the NASA Contract
- Work has begun on adding IDIQ tasks to the new contract



JOINT ARMY NAVY NASA AIR FORCE

INTERAGENCY PROPULSION COMMITTEE



CADRE

CENTER FOR AEROSPACE - DEFENSE
RESEARCH AND ENGINEERING



JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

NIRPS Provides Propulsion Industrial Base Analysis

Propulsion Supplier Integrated Modeling and Analysis (PropSIMA)

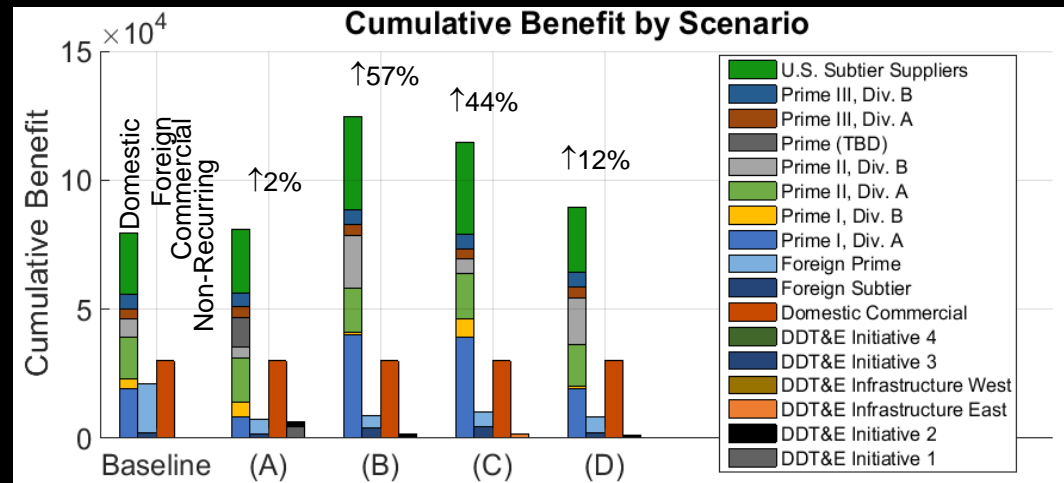
- Supplier Database (over 600) and Simulation Tool for Scenario Analysis
- Managed by NIRPS, with collaboration from USAF
- Building a leading edge capability to model the supply chain and industrial base for rocket propulsion

Previous Studies: PropSIMA assessed impact on RPIB due to three SLS Upper Stage Engine Options

Current Studies: Collaborating with USAF SMC, to analyze and update the suite of vehicles/engines, Courses of Action and results

- Domestic production of hydrocarbon booster propulsion
- Follow-on EELV acquisitions
- Restart of SLS RS-25 engine
- SLS Advanced Booster
- Advanced Upper Stage Engine
- Commercial Entrants

Metrics Studies: Collaborating with the Department of Commerce to develop and trend RPIB metrics and critical supplier pedigrees



NIRPS Collaborates with all of the Equity Holders in Rocket Propulsion for the US Government

- The JANNAF Programmatic and Industrial Base (PIB) Executive committee integrates the working groups and has program, project and engineering senior managers
- The JANNAF PIB Senior Advisory Group consists of key senior executives and flag officers and sets the strategy for the JANNAF PIB
- NIRPS manages the JANNAF Administration and Support Contract
- NIRPS will leverage and support NASA Agency level initiatives through the Propulsion Capability Leadership Team, to provide analysis and recommendations



NASA MSFC Technology Development and Maturation Feeds NSS and Commercial Space



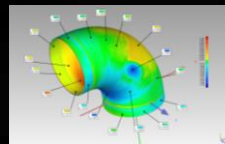
Exploration Propulsion Systems

Upper Stage Engine



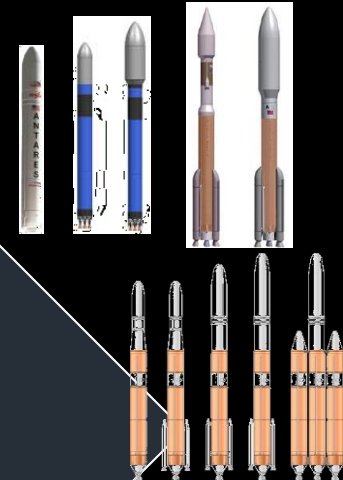
- LOX/Hydrocarbon engine design for booster and space exploration applications
- Additive Manufacturing
- Affordable RS-25 components
- Green Propellants
- Combustion stability analysis
- Lightweight cryogenic tanks
- Long duration cryogenic storage
- Advanced solid booster technologies
- Electric propulsion
- Structured Light Scanning

Advanced Boosters

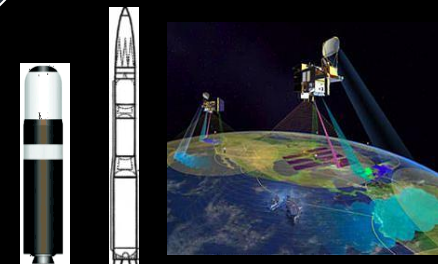


Advanced Manufacturing Demonstration (AMD)

Next Generation Space Launch



NSS Space



RS-25 Affordability



**>700 Welds Eliminated
>700 Parts Eliminated**



RS-25 Engine

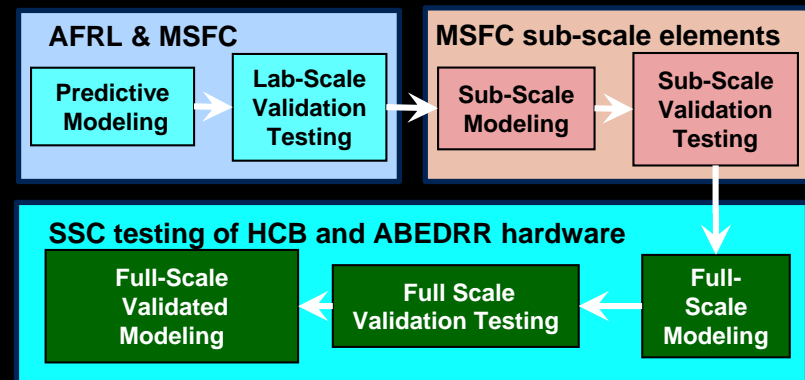
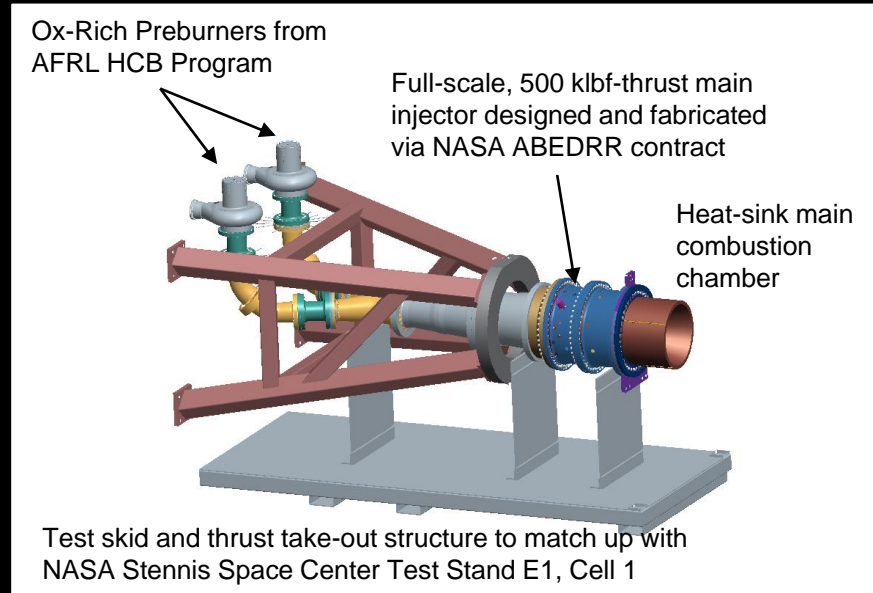


SLS Solid Rocket Booster - Qualification Motor 1



USAF SMC / NASA MSFC Launch and Propulsion Technology Maturation Efforts

- Integrated Ox-Rich Test Article (IOTA) – Full-scale (500klbf thrust), Lox/RP oxygen-rich staged combustion technology maturation effort
 - USAF Space and Missile System Center – coordination and funding source
 - NASA Advanced Booster Engineering Demonstration and Risk Reduction (ABEDRR) contract with Dynetics/Aerojet Rocketdyne
 - USAF Hydrocarbon Boost Program (HCB - conducted via AFRL)
 - NASA SSC unique facilities and experience – test stand E1
- Combustion Stability Technology Development – subscale oxygen-rich staged combustion stability demonstration, model development, and model validation
 - USAF Space and Missile System Center
 - Georgia Tech University
 - NASA MSFC
 - Air Force Research Lab
 - Purdue University



Retiring the Highest Risk of Combustion Stability

NASA MSFC Actively Pursuing Opportunities for Enhanced Design and Development via Advanced Manufacturing



Oxygen/hydrogen, open expander cycle, dual pumps w/ turbines in series

Technology development and demonstration to enable industrial advancement in rocket engine manufacturing



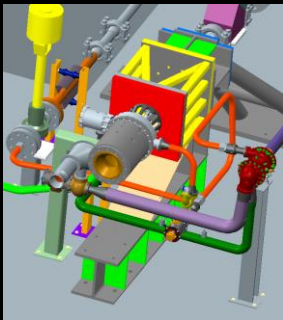
| Parameter | Value | |
|-------------------------------------|----------|----------|
| Engine Height | < 90 in | |
| Engine Diameter | < 70 in | |
| Starts | 15 | |
| Life (Cumulative) | 3,500 s | |
| Nozzle Exit Diameter | 20.7 in | |
| Nozzle Area Ratio | 26.92 | |
| | 70% | 100% |
| Vacuum Thrust (lb _f) | 24,828 | 35,352 |
| Sea Level Thrust (lb _f) | ~ 20,000 | ~ 27,000 |
| Vacuum ISP (s) | 451.9 | 452.0 |
| Mixture Ratio (Inlet) | 5.88 | 5.88 |
| Mixture Ratio (TCA) | 6.70 | 6.70 |
| LH2 Flow Rate (lb _m /s) | 8.0 | 11.37 |
| LOX Flow Rate (lb _m /s) | 47.0 | 66.85 |
| Chamber Pressure (psia) | 980 | 1,400 |
| LH2 pump speed (RPM) | 85,640 | 91,500 |
| LOX pump speed (RPM) | 21,900 | 27,500 |



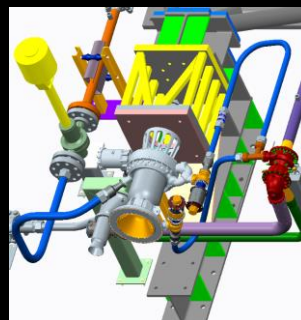
Breadboard Engine (current)

Incremental Development Path

Full Development Prototype Engine



Fuel pump/injector/ablative chamber (& valves, turbine bowls)



Add regeneratively-cooled combustion chamber



Add oxidizer pump (& more valve elements)

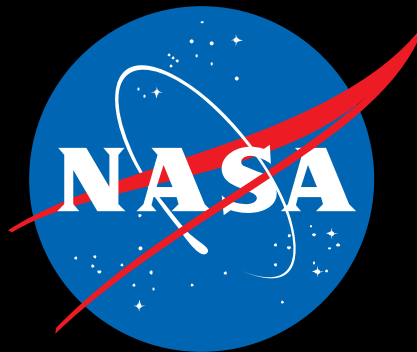


Add nozzle and system lines and ducts

Summary

- NIRPS is influencing US Government Policies by leading and supporting RPIB studies and analyses such as the NDAA 1095 Study, the PropSIMA Scenario Analysis Capability and the Domestically-Produced Engine Studies
- Via the JANNAF PIB, NIRPS is playing a leading role in integrating data and analysis and synchronizing programs across the rocket propulsion industrial base, providing senior leaders with the information needed to make informed decisions
- NIRPS is coordinating and advocating key propulsion technology advances and developments for a vibrant rocket propulsion industry

NIRPS has adapted its implementation strategies to the current environment



www.nasa.gov/marshall

Senior Advisory Group Membership

| JANNAF Programmatic & Industrial Base Senior Advisory Group (SAG) | | | | |
|---|---------------------|---|-------------|---|
| Title | First Name | Last Name | Dept/Agency | Title |
| Dr. | L. Dale | Thomas (Co-Chair) | NASA | Associate Center Director, Technical, NASA/MSFC |
| Mr. | Andre' | Gudger (Co-Chair) | OSD | Deputy Assistant Secretary of Defense (Manufacturing & Industrial Base Policy) DASD (MIBP) |
| Dr. | Spiro G. | Lekoudis | OSD | AT&L/R&E/Research and Engineering |
| Mr. | Dyke | Weatherington | OSD | AT&L/SIO Deputy Assistant Secretary of Defense for Space and Intelligence |
| Mr. | Barry | Pike | USA | Deputy PEO, Missiles and Space |
| VADM | Terry | Benedict | USN | NAVY/Director Strategic Systems Programs |
| Dr. | Claire | Leon | USAF | Executive Director for Space Launch Enterprise |
| Dr. | Billy W. | Mullins | USAF | SAF/A-10 Assistant Chief of Staff, Strategic Deterrence & Nuclear Integration |
| | | | USAF | SAF/EA4S, Executive Agent for Space |
| Maj Gen | Scott | Jansson | USAF | AFPEO/SS Program Executive Officer for Strategic Systems |
| Mr. | William | Hill | NASA | NASA/HQ/CM Deputy Associate Administrator for Exploration Systems Development |
| Mr. | Benjamin | Neuman | NASA | NASA/HQ/CN Division Director for Human Spaceflight Capabilities |
| Mr. | Jim | Norman | NASA | NASA/HQ - Assistant Associate Administrator for Launch Services |
| Ms. | Karen | Borrows | USN | Executive Director/SEA 00VW Naval Ordnance Safety and Security Activity Indian Head, MD 20640 |
| Ms. | Patricia | Gore | OSD/MDA | MDA/ECM Director, Industrial Manufacturing and Technology |
| Brig Gen Maj Gen | Anthony J. Steve | Cotton Denker (Summer 2015 process in) | NRO | Deputy Director, National Reconnaissance Office |

PIB Executive Committee Membership

| JANNAF Programmatic & Industrial Base Executive Committee (PEC) | | | | |
|---|------------|-------------------|------|---|
| Title | First Name | Last Name | | Affiliation |
| Dr. | Rajiv | Doreswamy (Chair) | NASA | NASA/MSFC |
| Mr. | Robert | Read (Co-Chair) | OSD | OSD-ATL |
| Dr. | Kendall | Brown (Alt Chair) | NASA | NASA/MSFC |
| Dr. | Christine | Michienzi | OSD | OSD-ATL |
| Mr. | Stuart | Blashill | USN | NAVY/China Lake |
| Mr. | Shahab | Chaudhry | USN | NAVY/SSP |
| Mr. | Frank | Tse | USN | NAVY/NSWCIHD |
| Mr. | Andy | Culbertson | OSD | OSD/R&E |
| Mr. | Drew | DeGeorge | USAF | AF/AFRL/RQR |
| Mr. | James | Fernandez | USAF | USAF/PEO/SP Space Launch Enterprise |
| Maj | Tim | Purcell | USAF | USAF/EA4S |
| Lt Col | Bill | Barrington | USAF | USAF/A10 |
| Dr. | Jamie B. | Neidert | USA | ARMY/AMRDEC |
| Mr. | David | Tritt | USA | Army/PEO M&S |
| Mr. | John | Honeycutt | NASA | NASA/MSFC/SLS Program |
| Dr. | George | Schmidt | NASA | NASA/GRC |
| Mr. | Thomas | Williams | NASA | NASA/MSFC/Engineering |
| Lt Col | Mark | Cinnamon | NRO | NRO/OSL |
| Ms. | Megan | Meisner | MDA | Industrial Manufacturing and Technology |

PIB Working Group Membership

| JANNAF Programmatic & Industrial Base Large Liquid Propulsion Working Group | | | | |
|--|------------|--------------|------|-------------------------------------|
| Title | First Name | Last Name | | Affiliation |
| Dr. | Kendall | Brown (Lead) | NASA | NASA/MSFC/FP30 |
| Mr. | Drew | DeGeorge | USAF | AF/AFRL/RQR |
| Mr. | James | Fernandez | USAF | USAF/PEO/SP Space Launch Enterprise |
| Maj | Lee | Kashka | USAF | USAF SMC/LRE |
| Mr. | Bill | Jacobs | NASA | NASA/MSFC/SLS |
| Mr. | George | Simone | NASA | NASA/LSP |
| Lt Col (s) | Tim | Purcell | USAF | SAF/SP/EA4SS |
| Ms. | Dayna | Ise | NASA | NASA/MSFC/FP30 - Commercial Crew |
| Mr. | Robert | Read | OSD | OSD/ATL/MIBP |
| Mr. | Kevin | Dickens | NASA | NASA/GRC |

| JANNAF Programmatic & Industrial Base Small Liquid Propulsion Working Group | | | | |
|--|------------|---------------|------|-------------------------------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | Chuck | Pierce (Lead) | NASA | NASA/MSFC |
| Mr. | James L. | Cannon | NASA | NASA/MSFC/ER01 |
| Mr. | James | Fernandez | USAF | USAF/PEO/SP Space Launch Enterprise |
| Mr. | Drew | DeGeorge | USAF | AF/AFRL/RQR |
| Mr. | Robert | Read | OSD | OSD-ATL |
| Mr. | Dmitriy | Plaks | USA | Army/MDA |
| Mr. | Kevin | Dickens | NASA | NASA/GRC |

| JANNAF Programmatic & Industrial Base Science & Technology Working Group | | | | |
|---|------------|-----------------|------|----------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | Drew | DeGeorge (Lead) | USAF | AF/AFRL/RQR |
| Mr. | James L. | Cannon | NASA | NASA/MSFC/ER01 |
| Mr. | Andy | Culbertson | OSD | OSD/R&E |
| Dr. | Christine | Michienzi | OSD | OSD-ATL |
| Mr. | Scott | Fuller | USN | USN/NAWC |
| Mr. | Mark D. | Klem | NASA | NASA/GRC-RPP0 |
| Mr. | Carlos | Lopez | USN | NAVY/SSP |
| Ms. | Megan B. | Meisner | MDA | MDA/DEC |
| Dr. | Jamie B. | Neidert | USAF | ARMY/AMRDEC |
| Mr. | Bob | Read | OSD | OSD-ATL/MIBP |
| Mr. | David | Tritt | USAF | Army/PEO M&S |
| Mr. | Richard | Ryan | NASA | NASA/MSFC/EE |
| Mr. | Michael | Meyer | NASA | NASA/GRC |

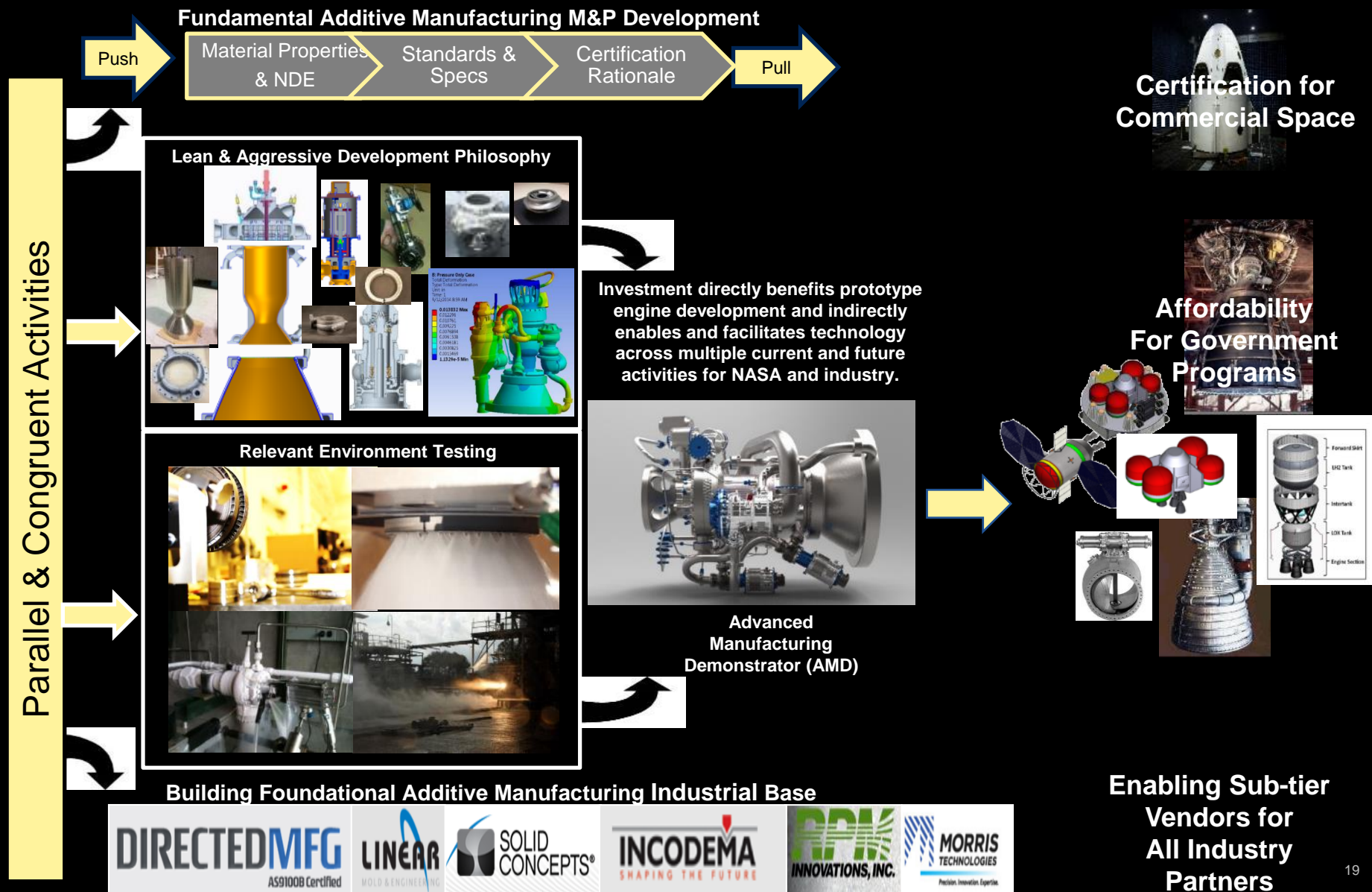
| JANNAF Programmatic & Industrial Base Large Solid Rocket Motor Working Group | | | | |
|---|------------|-----------------|------|-------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | Shahab | Chaudhry (Lead) | USN | NAVY/SSP |
| Mr. | David | Olsen | USN | NAVY/SSP |
| Dr. | Carlos | Lopez | USN | NAVY/SSP |
| Dr. | Christine | Michienzi | OSD | OSD-ATL |
| Mr. | Alex | Priskos | NASA | NASA/MSFC |
| Mr. | Mark | Cooper | NASA | NASA |
| Lt Col | Bill | Barrington | NASA | USAF/A10 |
| Mr. | Drew | DeGeorge | USAF | AF/AFRL/RQR |
| Mr. | Kirk | Newman | OSD | MDA |
| Mr. | Robert | Read | OSD | OSD-ATL |

| JANNAF Programmatic & Industrial Base Small Solid Rocket Motor Working Group | | | | |
|---|------------|------------|------|-----------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | Frank | Tse (Lead) | USN | NAVY/NSWC/HD |
| Mr. | Al | Stern | USN | USN/NSWC/HEODTD |
| Mr. | Nolan | Walton | USN | NAVY/SSP |
| Mr. | Stuart | Blashill | USN | NAVY/China Lake |
| Dr. | Christine | Michienzi | OSD | OSD-ATL |
| Mr. | David | Tritt | USA | Army/PEO M&S |
| Mr. | Kevin | Blacklock | USA | Army/AMRDEC |
| Dr. | Jamie B. | Neidert | USA | ARMY/AMRDEC |
| Mr. | Drew | DeGeorge | USAF | AF/AFRL/RQR |
| Mr. | Mark | Cooper | NASA | NASA/MSFC |
| Mr. | Steven | Harvison | NASA | NASA/MSFC |
| Mr. | Kirk | Newman | OSD | MDA Aegis BMD |
| Mr. | Robert | Read | OSD | OSD-ATL/MIBP |

| JANNAF Programmatic & Industrial Base Test & Evaluation Working Group | | | | |
|--|------------|--------------|------|-------------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | Mark | Moody (Lead) | NASA | NASA/SSC/RPT/TA00 |

| JANNAF Programmatic & Industrial Base Electric Propulsion Working Group | | | | |
|--|------------|-----------|------|-------------|
| Title | First Name | Last Name | | Affiliation |
| Mr. | David | Jacobson | NASA | NASA/GRC |

NASA MSFC Actively Pursuing Opportunities for Enhanced Design and Development via Advanced Manufacturing to Enable Future Propulsion



Using Actual Design, Development, and Test Activity to Learn the New Paradigms of Advanced Manufacturing



Test Stand 116



MCC Liner



Main Fuel Valve
Cryogenic Test



Full Scale
Injector
Water Flow



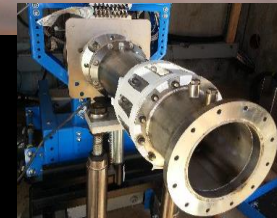
Sub-scale Injector Test



Turbine Exhaust Bowls

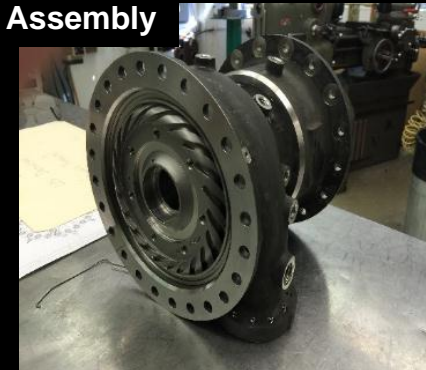


Turbine
Test Rig



Fuel Pump Assembly

Injector Assembly



OTBV



MFV

FTP and OTB Bowls



Using Actual Design, Development, and Test Activity to Learn the New Paradigms of Advanced Manufacturing

